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(NASA-CR-150845) SKYLAB VISCOUS DAMPER STUDY Final Report (General Electric Co.) 19 p HC A02/MF A01 CSCL 22B

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FINAL REPORT

SKYLAB VISCOUS DAMPER STUDY

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FINAL REPORT

SKYLAB VISCOUS DAMPER STUDY

CONTRACT NO. H-34352B

GENERAL ELECTRIC COMPANY

SPACE DIVISION

VALLEY FORGE SUPPORT DEPARTMENT

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NOVEMBER 1978

Prepared for:

NASA-MARSHALL SPACE FLIGHT CENTER

HUNTSVILLE, ALABAMA

1.0 SUMMARY

GE conducted a study for NASA-MSFC to evaluate the potential application of a magnetically anchored viscous fluid damper to the Skylab Reboost Mission. Principle objectives of the study were:

- Determine whether the proposed concept and design can provide the damping required to maintain Skylab in a gravity-gradient passive stabilization mode, and determine the Skylab and Teleoperator Retrieval System (TRS) related parameters that will influence the damper performance.
- Determine the optimum size, weight and configuration of the required damper. Evaluate the need for a magnetic particle shield and the maximum allowable magnetic materials located in the vicinity of the damper, as a function of distance.
- Using existing techniques and extrapolations from existing data references, study the operating characteristics of the proposed damper.

2.0 RESULTS

The proposed magnetically anchored viscous fluid damper can maintain the Skylab in a gravity-gradient stabilized mode at the anticipated reboost altitudes. The parameters influencing damper performance (and thereby affecting the degree of risk) are:

- Amount of Skylab pitch bias in the orbit plane which will result from aerodynamic trim conditions of the post-reboost configuration Skylab. (Reference: Figure 9)
- The lowest altitude to which the post-reboost Skylab will be allowed to decay prior to the next rendezvous. (Reference: Figure 9)
- Maximum allowable weight and size of the proposed damper in order to match shuttle/TRS mission constraints. (Reference: Figures 8 and 9)
- The amount of magnetic materials expected to be in the vicinity of the damper. (Reference: Figure 11)

A 600 pound, 28 inch magnet sphere diameter damper will achieve the desired results with low risk of failure to maintain stability. The damper will be of the general configuration of Figure 10, except that no pyrolytic graphite is presently anticipated to be required.

The allowable amounts of permanent magnet material in the vicinity of the damper are presented in Figure 11 as a function of distance from the damper. A final determination of whether a magnetic contaminant shroud will be required will be addressed in the next phase of the contract.

The operating characteristics of the proposed damper were studied using existing techniques and extrapolations of existing data. (Reference: Figures 2, 3, 4, 5, and 6). Results of this linearized analysis indicate low risk of stabilization failure for the proposed size damper (Reference: Figure 9), but all-up system simulation must be undertaken (as part of the proposed problem) in order to obtain the required confidence in the performance predictions.

3.0 BACKGROUND

- NASA wishes to reboost Skylab (approximately February/March 1980) from its present orbit (165 - 170 NM) to 260 NM in order to prolong its life in orbit and minimize the potential threat of uncontrolled re-entry and surface impact.
- Upon attainment of its new orbit, Skylab must be stabilized in order to allow subsequent docking by a TRS for possible additional reboost or deboost. Subsequent docking by a manned vehicle is also possible. Stabilization in this case is principally aimed at limiting attitude rates to allow subsequent docking. Gravity-gradient has been selected as the preferred mode since it is entirely passive, even though it is the maximum profile drag attitude.

3.0 BACKGROUND (continued)

- o TRS will not be able to re-dock with Skylab and successfully deboost it to a specified target zone on the ocean surface at altitudes above 170 NM. It is understood that this limit is due to energy limit for deboost and to rendezvous television range limits (shuttle is expected to be orbiting at 150 NM at this time and the crewman controlling the rendezvous will be in the aft flight deck).

- o GE was asked to conduct a study to determine the feasibility of fabricating a damper which, in conjunction with Skylab's inherent high inertia ratio, would stabilize Skylab in the G-G mode at its new altitude and would continue to provide attitude rate stabilization down to 150 NM to 170 NM, as the orbit once again decays.

  (Reference: Statement of Work H-34352B, Dated 10/2/78)

  Work was started based on a telecon from Jack Swearingen, Marshall Space Flight Center (MSFC), 10/4/78.

- o Very little systems analysis (and no systems simulation) was possible in the extremely short time alloted. Accordingly, GE agreed to pursue a 120 ft-lb-sec damping coefficient on recommendation by NASA-MSFC (which level was derived from a ten year old GE study on stabilizing the S IV-B wet workshop). First estimates of magnetic dipole required were 10×10^6 to 20×10^6 pole-centimeters.

- o A series of damper configurations were developed based on this dipole, starting at the conservative upper limit (and with little weight and size trimming) since NASA's sensitivity to either parameter was unknown. Phone calls to NASA to determine which parameter should be optimized revealed sensitivity to both parameters and a strong desire to minimize weight. However, no definite weight limit was defined until the October 12 phone call, at which time NASA asked GE what could be done for a 200 lb. limit. This result was reported on the October 13 phone call, at which time cautions were relayed to NASA that a high risk of instability existed at the level of dipole attainable at this extremely low weight.

  Figure 1 summarizes the damper sizes and weights relayed to NASA from October 6 to October 13.

- o Late on October 13, Mr. Swearingen called Mr. Foster expressing concern over the several damper sizes and weight inputs received from GE by telecon that week and seeking an evaluation of the degree of risk involved in accomplishing the total mission objectives. A meeting was planned for 17 and 18 October between NASA-MSFC and GE-SD personnel at which these issues would be probed in greater depth.

4.0 DISCUSSION

Mr. Harry Buchanan, Mr. Raymond L. Gause and Mr. Irvin (Tom) Morgan, all of NASA-MSFC, met with the following GE-VFSD personnel at Valley Forge on 17 and 18 October 1978:

Leroy Foster	Howard Foulke	Joe Totaro
Tom McLay	Dave Purdy	Don Matteo
Sandy Weinberger	Gerry Marello	Gene Tyrell

Significant answers provided by NASA during the meetings are:

- Skylab is in a 50° inclination orbit.
- Gravity-gradient stabilization will not be required during any future manned occupancy of Skylab.
- Shuttle will be limited to 150 NM altittude during the planned mission.
- Of the previously reported 8° "pitch" bias (150 NM, nominal atmospheric density), the component actually in the orbit plane is only 6°. Similar ratio exists for other reported "pitch" biases. (NOTE: Stability is sensitive to true orbit plane pitch bias.)
- Docking at the side docking port (close to S-193 Experiment) is now baseline for that portion of the assembly which will attach the damper to Skylab. Thus no man-rating required for docking tunnel, damper, etc.

  Docking at end docking port for TRS thrusting is still required.
- NASA's chief concern is, "Down to what altitude can the damper maintain stability since any subsequent deboost mission will be limited by TRS rendezvous/deboost limit of 150 to 170 NM?".

Presentations by GE were as follows:

- Howard Foulke presented Figures 2, 3, 4, 5, and 6. The important message from Howard's remarks were:
  - Flying a damper with severely limited M/I_p, (Magnetic Dipole/Pitch Moment of Inertia) is very risky because damping parameter ($b/I_p W_o$) is limited on the low side by Garber Instability (driven by Pitch Bias) and on the high side by magnetic "anchoring" capability.
  - Time and money for an all-up systems simulation must be allocated before the required confidence in performance prediction can be obtained.

    Accordingly, Howard presented a risk chart, similar to Figure 9, showing that prudent design practice could not tolerate magnetic dipoles below the 10×10^6 pole-cm range.

4.0 DISCUSSION (continued)

NASA stated that while the 200 pound limit was still very real (limited by TRS structural considerations), they would like us to develop parametric data showing damper weights as a function of required dipole and diameter in order to properly brief their management.

Accordingly, Figures 7, 8 and 9 were developed and presented on 10/18/78. Figure 8 shows the estimated damper weights as a function of Dipole, and for a family of diameters, for very agressively weight trimmed damper design.

Figure 9 is the bottom line. It shows degree of risk vs. the magnet dipole selected and defines weight and sizes for four dampers of various dipoles. All agreed that prudence would indicate operation to the right of 45° terminator between moderate and low risk zones. The most optimistic pitch bias NASA would speculate on was 4.5° for a 170 NM orbit with 2σ (high end) atmospheric density. This would require a 300 pound, 24 inch diameter damper.

NASA reviewed the GE inputs on required damper sizes, as well as their own assignment of how much weight could be allocated to the Damper System should the damper be totally supported during launch by the TRS System. NASA's conclusion is that a separate cradle to individually support the damper is required since no reasonable amount of additional weight can be supported by the TRS.

Accordingly, NASA requested scope of a program for a 600 pound, 28 inch diameter damper, which would be separately supported by its own cradle.

4.0 DISCUSSION (continued)

The results of this program scoping exercise were reported to NASA by telecon on 1 November 1978. They are:

- GE will provide a 600 pound, 28 inch (magnet sphere) diameter damper having a low risk of mission failure at the predicted worst case of eight degrees of pitch bias in the orbit plane. The approximate price will be about $ 1.1 Million on a CPFF basis.
- This damper will be delivered on 15 October 1979 assuming a 15 November 1978 start date.
- All other conditions of the quote remain the same as the letter from E. Tyrell to Jack C. Swearingen, dated 20 September 1978.

Figure 1.

SKYLAB DAMPER

SUMMARY OF DISCUSSIONS WITH MARSHAL

- OCTOBER 6

Dipole - 20×10^6 pole cm

Material - Alnico 5

Diameter	Magnet Weight	Total Weight
36"	500	650
32"	650	790
28"	800	920

- OCTOBER 12

Dipole - 10×10^6 pole cm - Nominal

Material - Alnico 5

Diameter	Dipole	Magnet Weight	Total Weight
24"	14×10^6	420	570
28"	11×10^6	300	450

- OCTOBER 13

Dipole - 6×10^6 pole cm - Nominal

Material - Alnico 5 - 7

Diameter	Dipole	Magnet Weight	Total Weight
20"	7×10^6	163	200

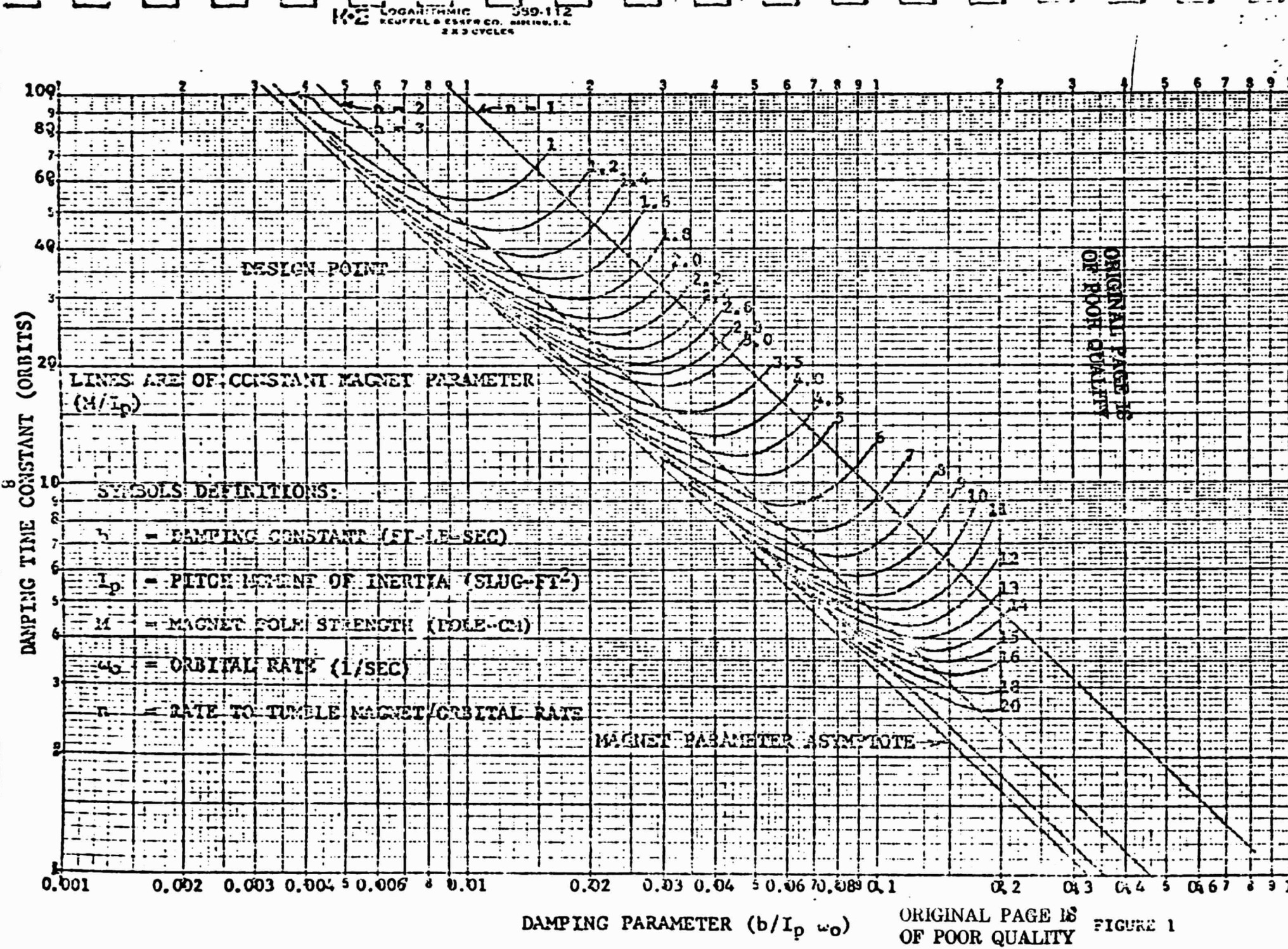

FIGURE 1

Figure 2.

GARBER STABILITY LIMIT

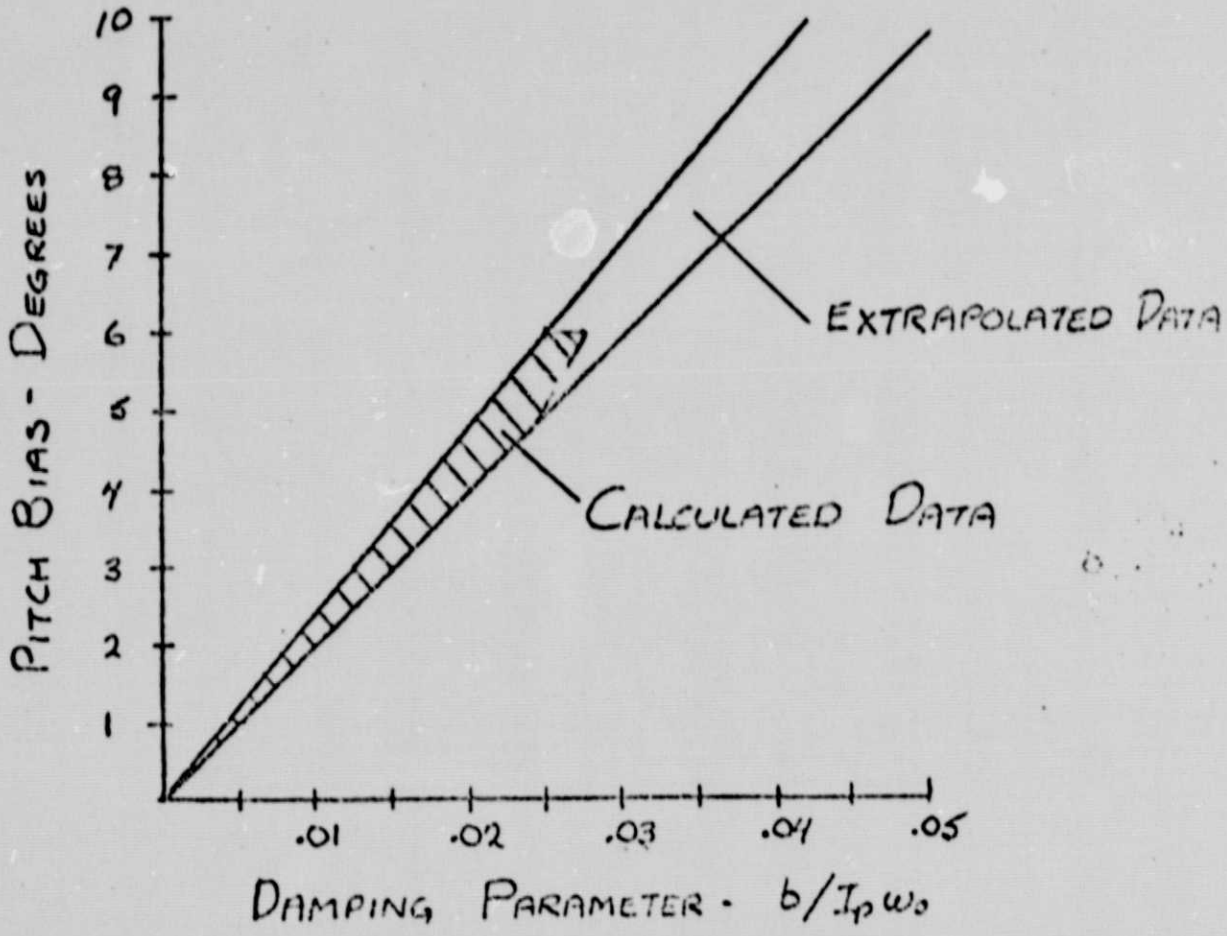

Figure 3.

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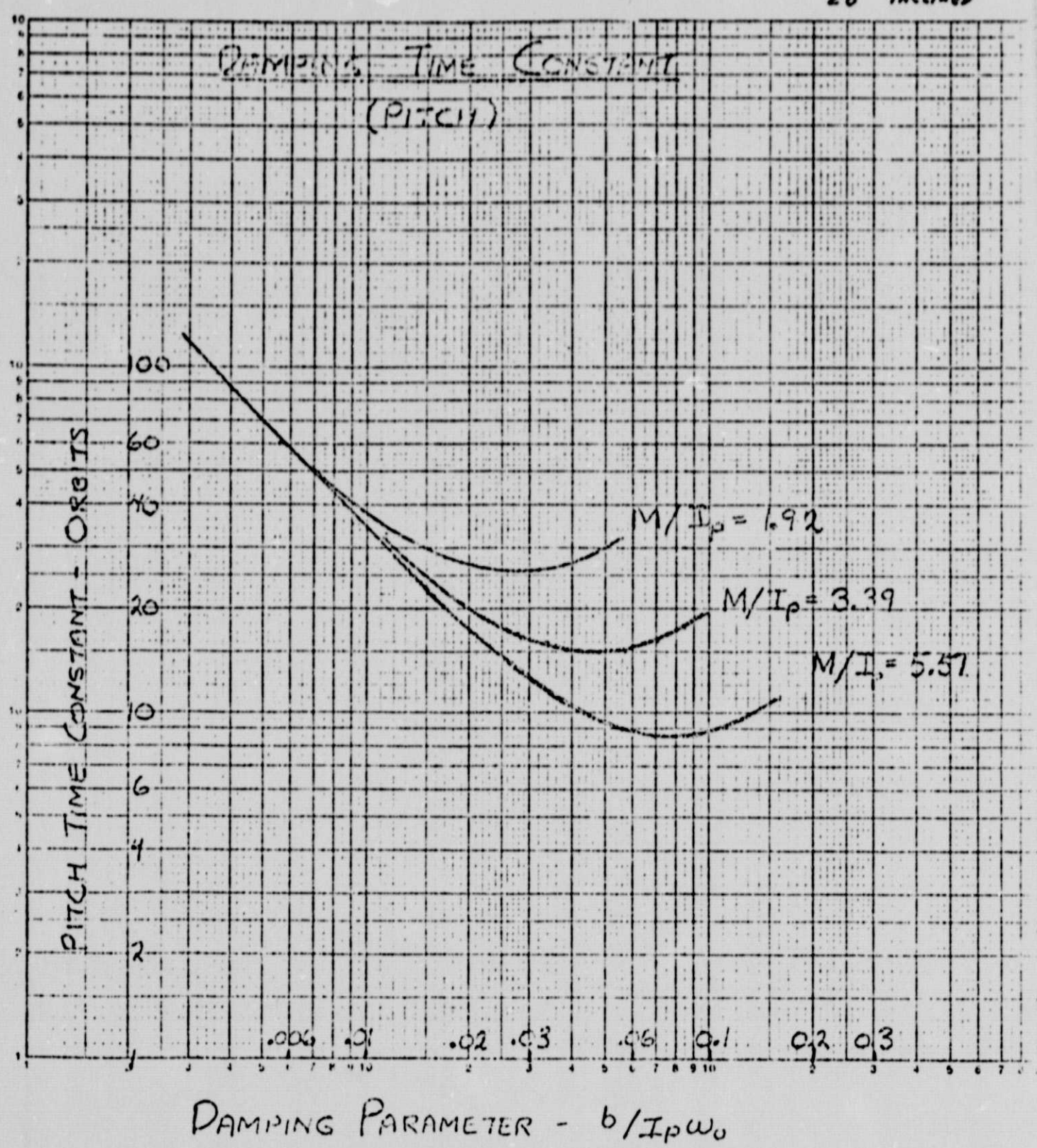

Figure 4.

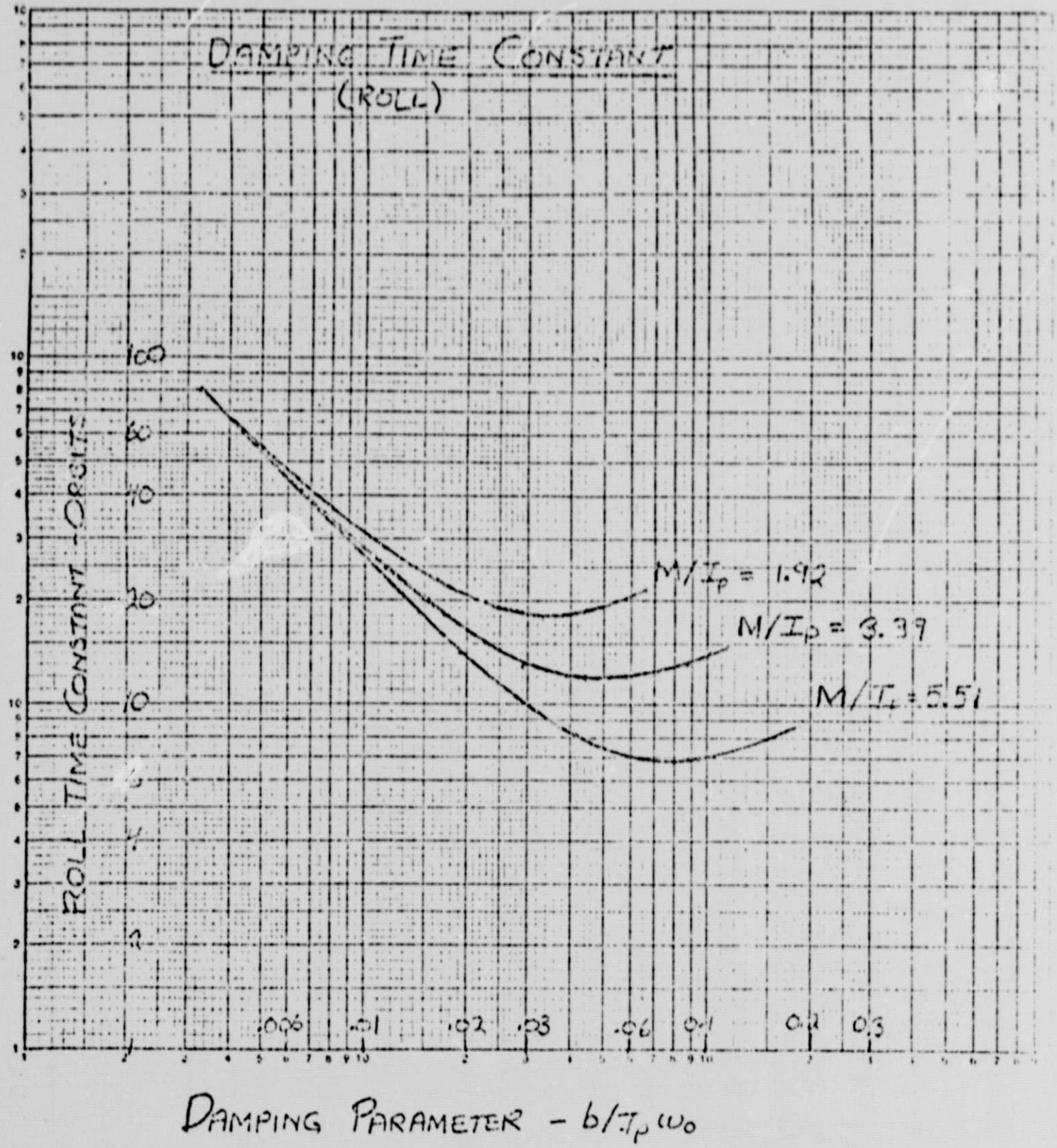
DAMPING TIME CONSTANT
(ROLL)
ROLL TIME CONSTANT - ORBITS
100
60
40
20
10
6
4
2
1
.06
.1
.2
.3
.4
.6
1
2
3
M/I_p = 1.92
M/I_p = 3.39
M/I_p = 5.51
DAMPING PARAMETER - b/I_p ω_o

Figure 5.

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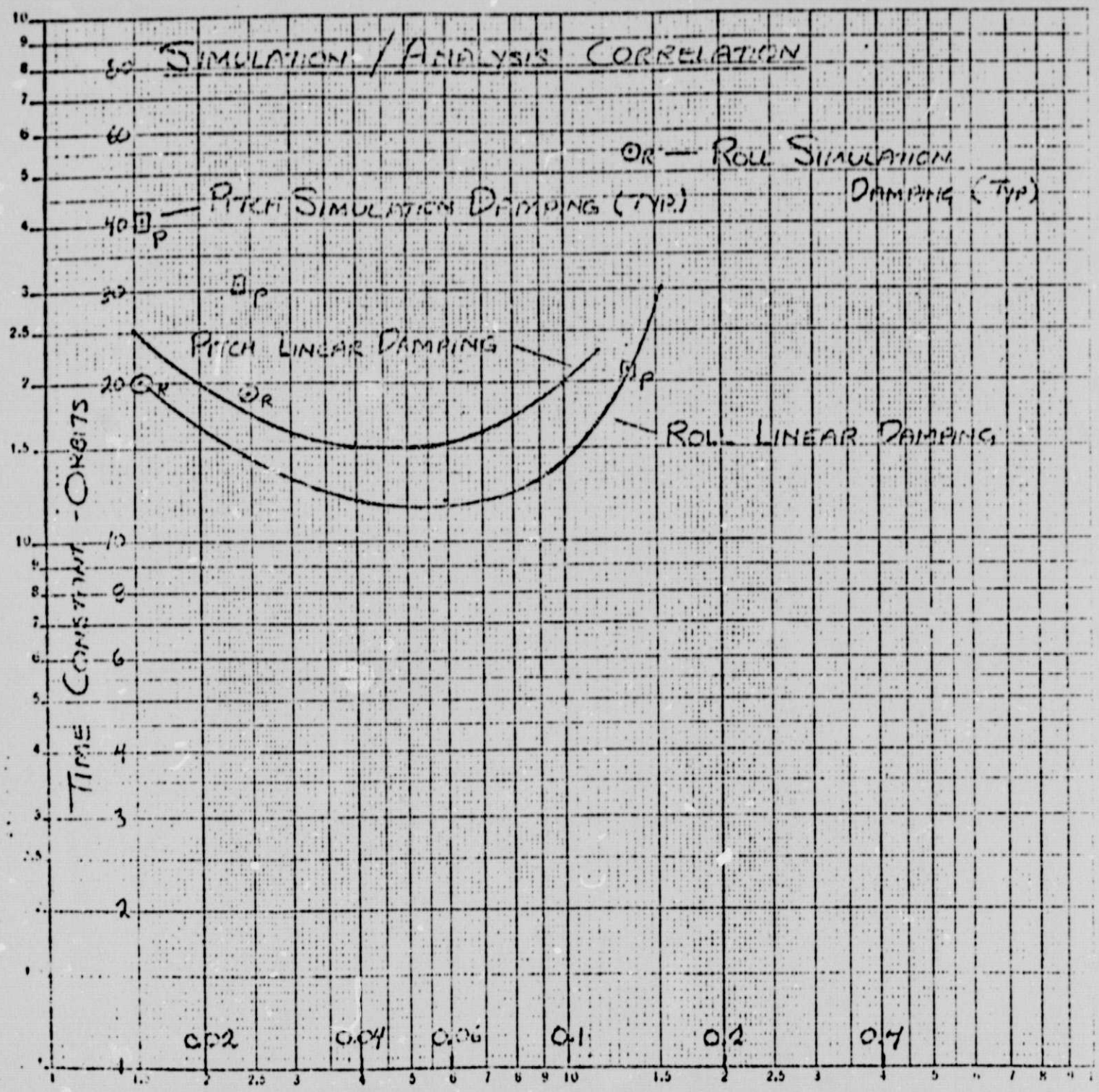

Figure 6.

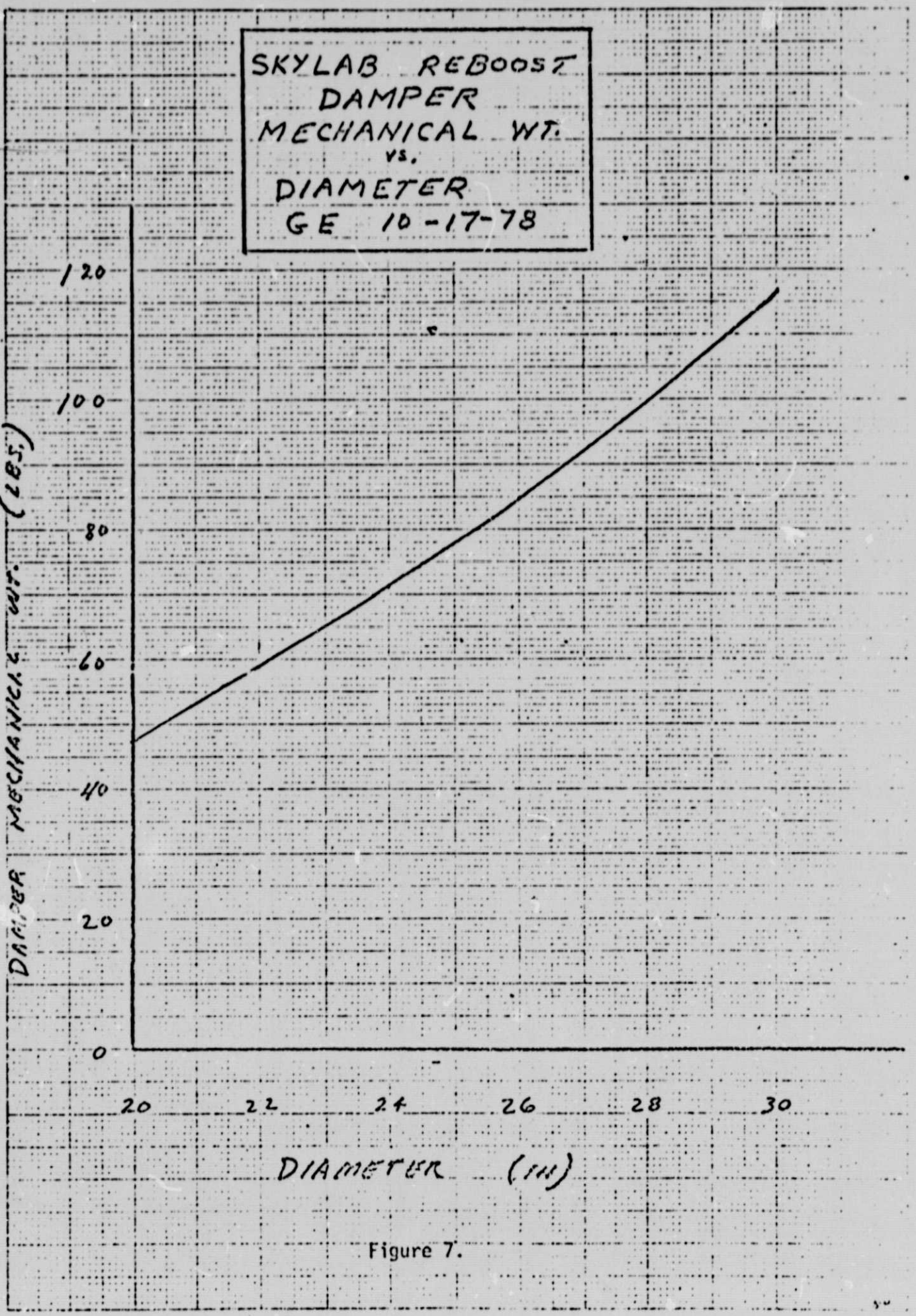

Figure 7.

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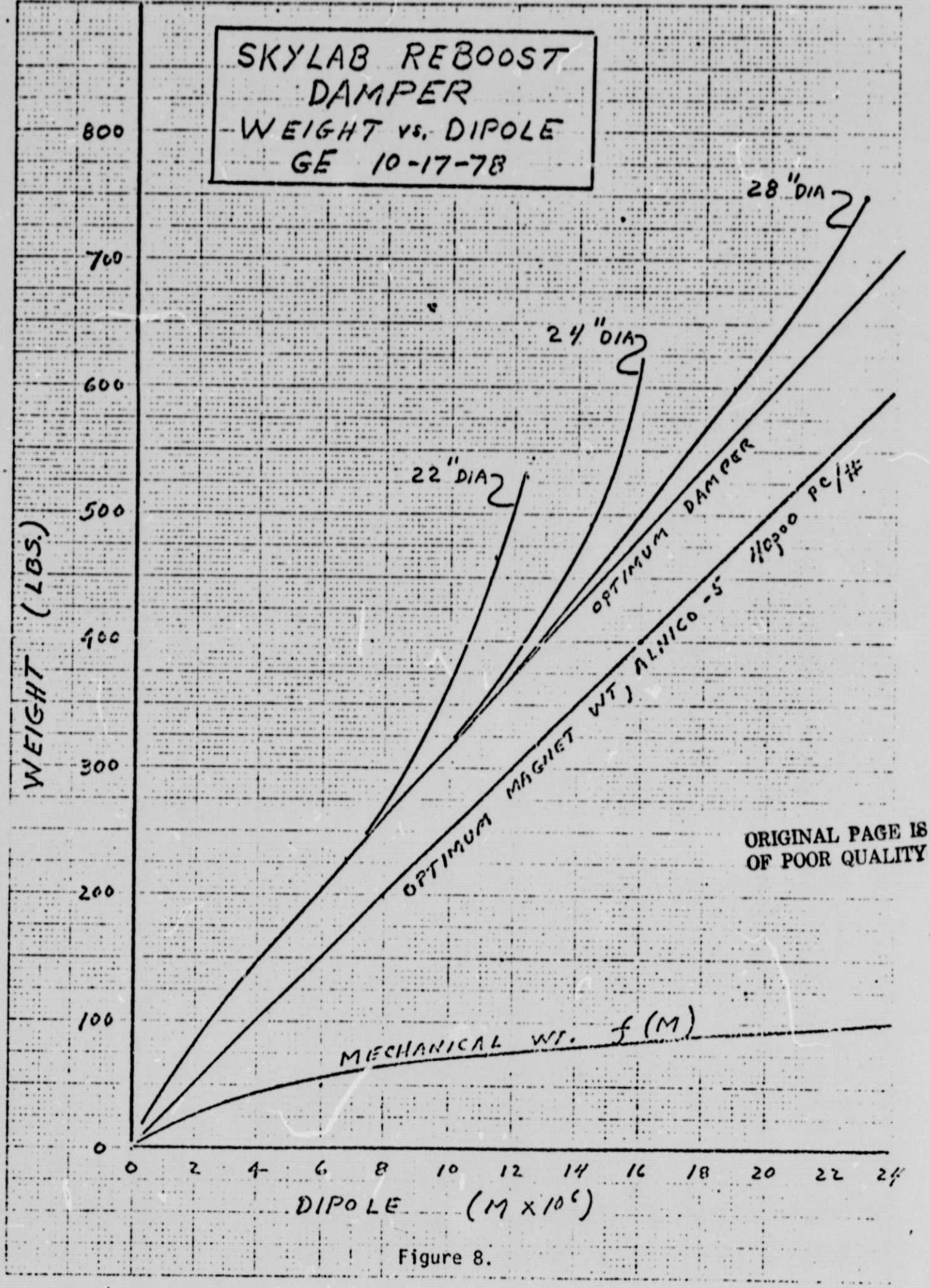

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Figure 8.

SKYLAB REBOOST DAMPER - RISK vs. WT.
GE 10-17-78

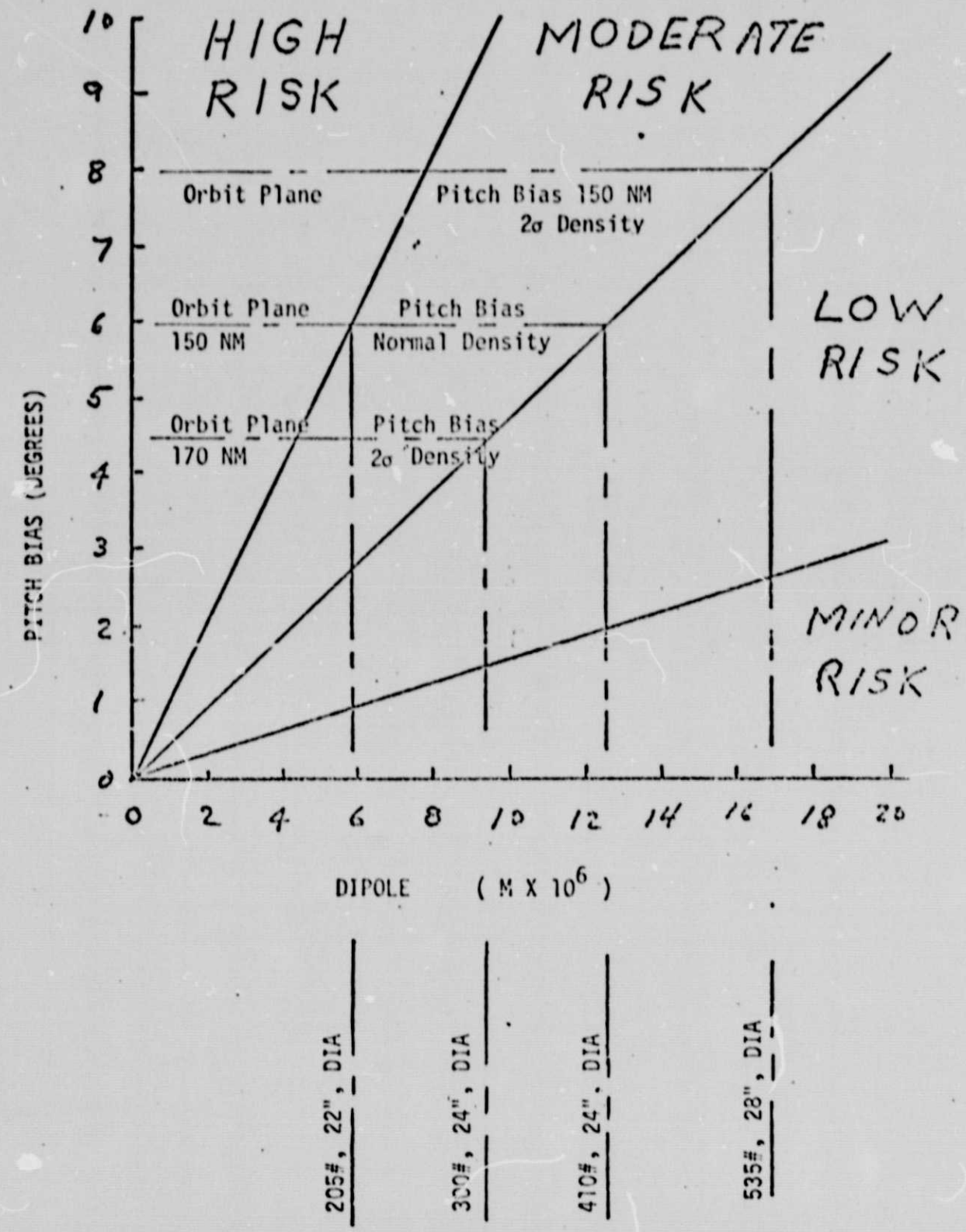

Figure 9

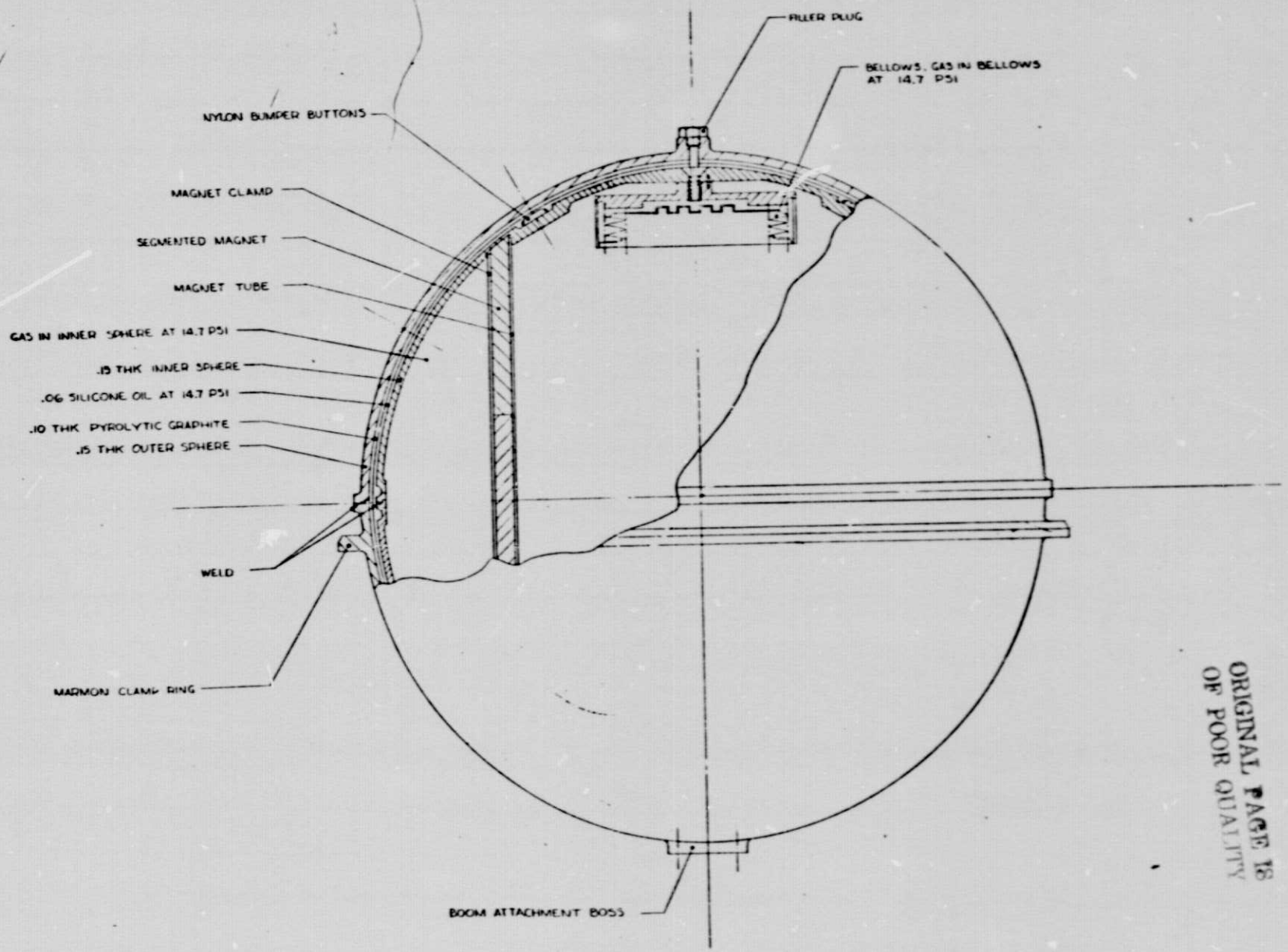

Figure 10.

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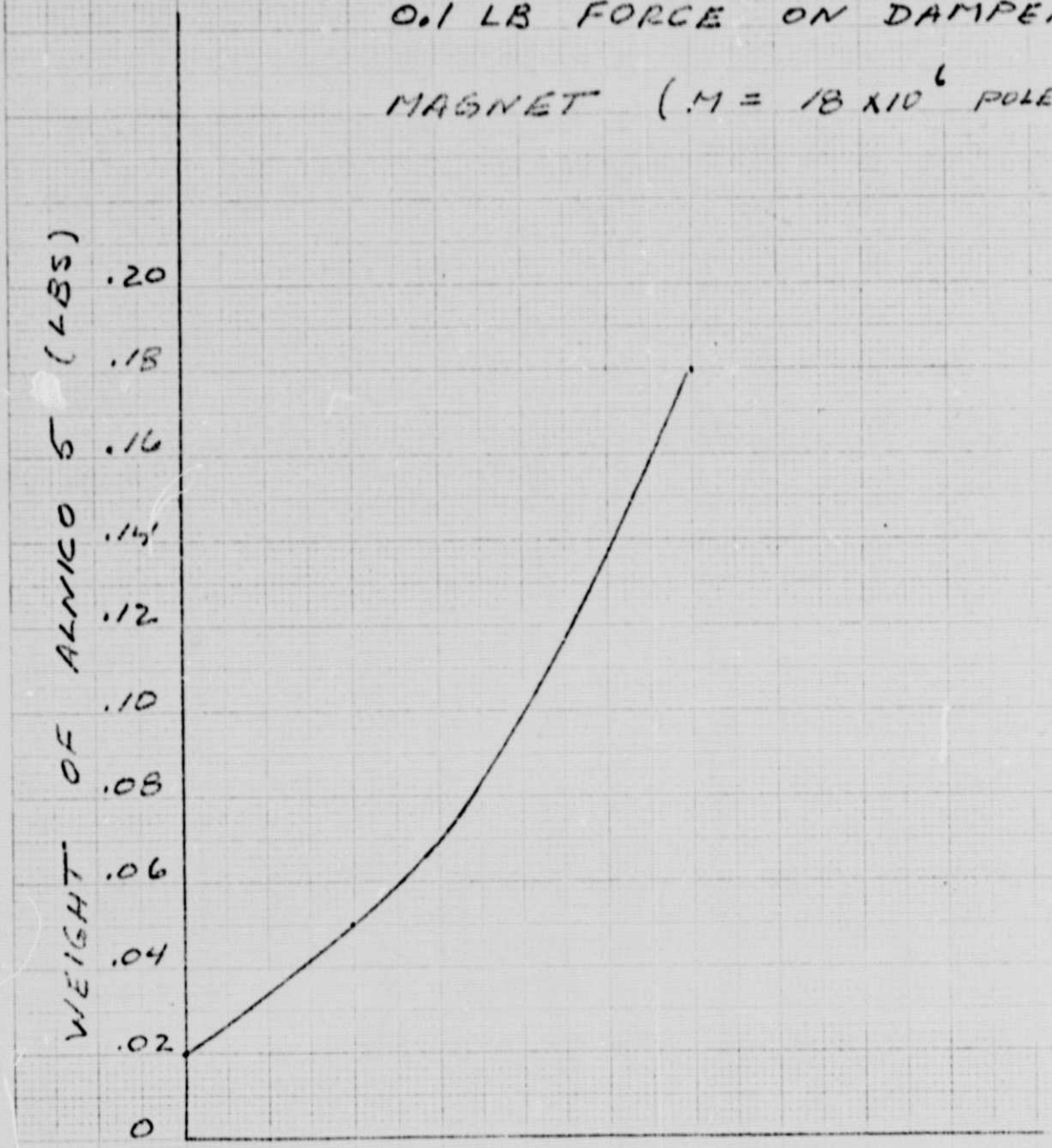
WEIGHT OF ALNICO 5
REQUIRED TO PRODUCE
0.1 LB FORCE ON DAMPER
MAGNET ($M = 18 \times 10^6$ POLE CM)



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